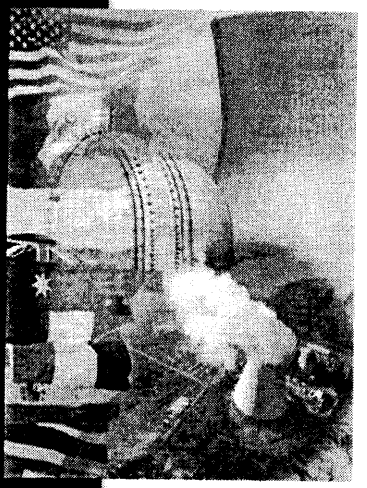


The EPRI Guide to Fire Modeling: An Overview

B. Najafi, F. Joglar,
Science Applications International Corp.

R. Kassawara
EPRI Project Manager

SAIC

EPRI

EPRI Perspective

Development of Core Technologies

Fire Modeling
Develop enhancements to fire modeling tools for:
- Ease of implementation in the field
- Use in promoting understanding of basic fire modeling principles
- Reducing cost of application

Operational Data
- Ensure fire events data is pertinent to risk and PB evaluations
- Determine reliability of fire protection systems

Fire Tests
- Validate fire modeling tools
- Verify fire characteristics
- Determine effectiveness of fire protection systems
- Determine fire damage

Fire Risk
Identify and address weakness in the fire risk evaluation methods

Implementation Guide

Standards NFPA-NML
Develop a guide for use of these methods and tools in the NFPA PB standards

Fire Risk / Performance Monitor
Develop methods / guide to measure / monitor risk-based and performance-based criteria using core technologies

Inspection / Enforcement
- Identify issues related to inspection and enforcement of a RI/PB rule

Cost / Benefit
Define most cost beneficial applications of RI / PB techniques

Application

RI / PB Fire Protection Program
How to use risk and performance information to improve a fire protection program

Case Studies
&
Pilot Applications

SAIC

8/19/2002

Slide: 2

EPRI

Outline

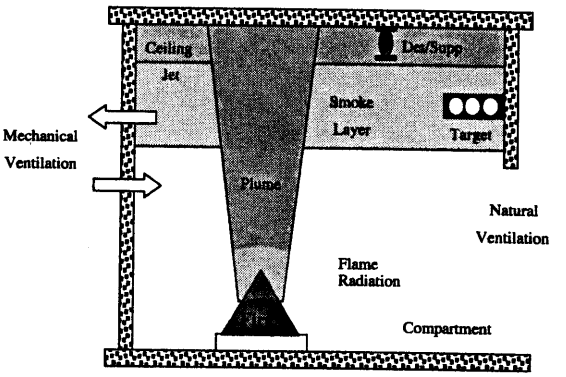
- Introduction
  - About fire modeling
  - Objectives
  - Fire Modeling Guidelines
    - Scope and development
- Steps to perform fire modeling
  - 5 steps to perform fire modeling
  - Supplemental guide
- Conclusions

Fire Modeling

- Fire modeling:
  - an approach for predicting various aspects of fire generated conditions inside a compartment
  - requires an idealization and/or simplification of the physical processes involved in fire events
- Any departure of the fire system from this idealization can seriously affect the accuracy and validity of the approach

Modeled Fire Phenomena

- Exposure
  - Fire Plumes
  - Ceiling jets
  - Upper layer
  - Flame radiation
- Effects
  - Heat detection
  - Target response
- Fire
  - Predefined intensity



Fire Modeling in Nuclear Power Plants

- NPP's present a number of fire modeling challenges
  - The ability to address all this challenges is usually restricted by model capabilities
  - A procedural approach can help practicing engineers through the process of fire modeling
- In response to the need for this procedural approach, EPRI developed the Fire Modeling Guidelines

Objectives of the Project

Develop a process through which fire protection engineers in commercial nuclear facilities may use fire modeling to support day-to-day operation of their facilities.

Use of the Guide

- The guide is a complement and not a substitute to:
  - fire dynamics text books
  - code validation studies
  - user's guide(s) for a particular code(s)
- The guide does not address the issue of selection of fire scenarios.
- Users with the following characteristics will benefit the most:
  - Understanding of algebraic equations
  - General knowledge on compartment fire behavior
  - General knowledge on basic engineering principles, specifically heat transfer and fluid mechanics

Development of the Guide

- Library of fire scenarios
- Modeling of fire scenarios
  - Scenario description
  - Prediction of fire conditions
- Lessons learned
  - The evaluation of the scenarios generated the knowledge base to develop the actual guidelines
- Methodology to perform fire modeling

Selection of Typical NPP Fire Scenarios

- US NPP design and operation
  - Typical geometries and equipment layouts
- Risk significance
  - Fire IPEEE
- Industry experience
  - Utility and NRC surveys: How and where fire modeling has been used in the past.

- Switchgear room
- Cable spreading room
- Main control room
- Pump room
- Turbine building
- Multi-compartment corridor
- Multi-level compartments
- Containment

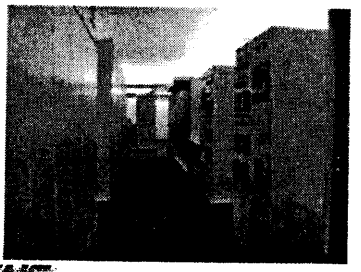
- Issues and challenges
  - High energy events
  - Fire barriers

Cable Spreading Room

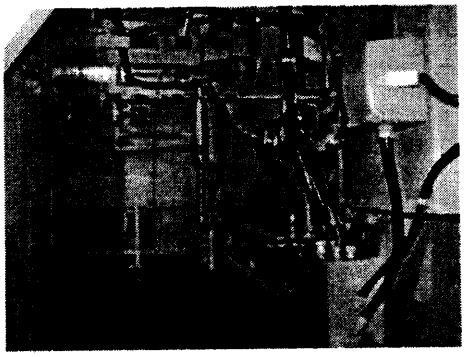
- Issues and challenges
  - Fire spread in cable trays; horizontal, vertical, or sloped
  - Fire propagation between cable trays; stack, parallel, or crossing
  - Congested ceiling (with cable trays) and impact on ceiling jet
  - Obstructed detection and suppression

Main Control Room

- Issues and challenges
  - Fire propagation inside Main Control Board
  - Panel-to-panel fire propagation and timing
  - Habitability



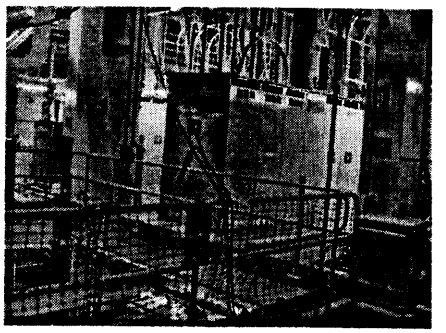
- Issues and challenges
  - Large fires in small compartments
  - Flashover
  - Integrity of boundaries



- Issues and challenges
  - Large fires in large enclosures
  - Non-concrete, open boundary
  - Hydrogen fires

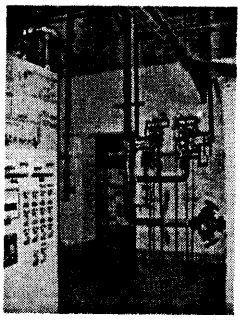
Multiple elevations

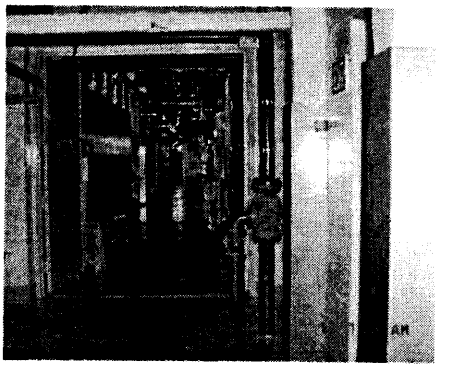
- Issues and challenges
  - Smoke/hot gas spread upward
  - Fire propagation to floors below
  - Size and location of opening and use of single- or multi-compartment model



Corridor

- Issues and challenges
  - Different ceiling heights
  - Soffits and their impact on propagation of hot gases





- The guide does not include a modeling example for the containment building
- Modeling issues in the containment building are addressed in other scenarios:
  - Large enclosure
  - Cylindrical boundaries
  - Domed ceiling

Hand Calcs	Zone Models	Field Models
• FIVE-Rev1 – Excel tool – Most of hand calcs in FIVE – DETACT – MQH room temperature model • Negligible calculation time	• CFAST (NIST) • MAGIC (EDF) • COMPBRN-IIIe • Calculation times in the order of minutes	• Not included in the guide • Calculation times in the order of hours to days

FIVE-Rev1

- Microsoft Excel tool with hand calculations included as Excel built-in functions.
- The library of functions include most of the hand calculations in FIVE plus the DETACT and the MQH models for detection and room temperature respectively
- The built in functions combined with Excel capabilities allow to perform sensitivity and uncertainty analysis.
- Available from EPRI

CFAST

- Developed in the 90's for a broad range of applications including buildings, power plants etc.
- DOS based software with a GUI interface
- Multi-fire, multi-room, multi target fire simulation
- Available from NIST

[illegible]

- Developed in the 90's by EDF for a broad range of applications including buildings, power plants etc.
- Windows based, user friendly graphical interface
- Multi-fire, multi-room, multi-target fire simulation
- Available from EPRI

[illegible]

- Developed in the early 80's mainly for nuclear applications
- Still a DOS computer application
  - Difficult to input modeling parameters (vs. Windows applications)
  - Difficult to evaluate modeling results (vs. Windows applications)
- Single compartment model with one opening
- Uncertainty Analysis
- Available from EPRI

Guide - Steps to Perform Fire Modeling

- Step 1: Define modeling objectives
- Step 2: Describe the fire scenario
- Step 3: Select appropriate model(s)
- Step 4: Estimate fire generated conditions
- Step 5: Verify and interpret results

Fire Modeling Guide Step 1

- Define modeling objectives
  - Need to be expressed in terms of output parameters from fire models
- Example
  - "Evaluate the temperature at the surface of the target"

Fire Modeling Guide: Step 3

- Describe the fire scenario
  - Compartment: geometry, ventilation, fire protection
  - Targets: location, flammability parameters, intervening combustibles
  - Fire: heat release rate
- Scenario characteristics are the basis for model selection
- The model may require more or less information than the one already collected.

Fire Modeling Guide: Step 4

- Select appropriate model(s)
  - The guide provides a table that summarizes the capabilities of each zone model
  - The characteristics of the scenario are required to use the table
  - Additional description may be required based on the specific inputs to the selected model(s)

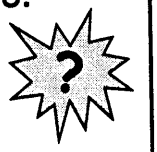
Fire Modeling Guide: Step 4

- Estimate fire generated conditions
  - Prepare input file to the model
  - Run the model
  - Process output file

Fire Modeling Guide: Step 5

- Verify and interpret results
  - Check if results are consistent with input parameters
  - Use the results to address the predefined objective

- In many fire scenarios, these 5 steps can not be readily implemented for reasons that include:
  - Enclosure geometry
  - Modeling capabilities
  - Input parameters



- Supplemental guidance in these areas help analyst perform fire modeling studies without compromising technical validity.
- Supplemental guidance is also provided in the area of interpreting fire modeling results

- Library of NPP fire scenarios
- Modeling examples of the library of fire scenarios
- Fire modeling guide
- Excel template: Five-Rev1

Conclusions

- Understanding of fire dynamics is essential:
  - Physical phenomena
  - Assumptions in the development of each model
  - Capabilities and limitations of each model
- Combination of modeling tools is usually necessary to evaluate complex situations in nuclear power plants
- The fire modeling guidelines help engineers to organize information and select appropriate models
- EPRI is preparing a two-day training course on compartment fire behavior and the use of the FM guide

Conclusions

- Areas where fire modeling can be applied
  - Thermal effects of plumes, ceiling jets and radiation
  - General room heat up, and hot gas layer
  - Elevated fires and oxygen depletion
  - Multiple fires
  - Multi-compartments: corridors and multiple elevations
  - Generation, migration and density of smoke
  - Partial barriers and shields
  - Detection

- Areas for future research
  - High energy fires: explosions
  - Hydrogen or liquid spray fires
  - Fire growth within main control board
  - Fire propagation between control panels
  - Fire suppression
  - Cable fires
- EPRI method uses empirical models based on a combination of operating experience and applicable fire tests to estimate consequences of such fires

- Duke Power
- Exelon
- Public Service Electric & Gas
- Pacific Gas & Electric
- EDF
- NIST
- NRC